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Replacing Imports of Crop Based Commodities by Domestic Production in Finland: Potential to Reduce Virtual Water Imports

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Global water scarcity is a severe threat facing humanity today and it is expected to become even more alarming in the future. Agriculture is the biggest user of freshwater and large volumes of embedded virtual water in food products are traded through the global food system annually. Although Finland has vast water resources, it imports large quantities of virtual water–partly from countries suffering from water scarcity. In this article, we present a novel combination of the virtual water study together with an analysis of the potential reallocation of the outsourced production of rice, soybeans and rapeseed, from the water resource-efficiency point of view. To assess how Finland could reduce the outsourced water consumption by these three crops, we evaluated Finland's potential to replace their imports with local comparable products: domestic barley and oats, field peas and faba beans, and rapeseed, respectively. This replacement would both potentially ease the global pressure on already stressed regions and increase the agricultural diversity of the local agricultural systems. We found that by replacing the imports of the selected crops, considering the realistic potential in Finland, up to 16% of the blue water and almost 30% of the green water embedded in crop imports could be reduced. Although Finland is a minor player in the global food markets, our study presents a highly relevant case of how an industrialized country, with a relatively small population, can contribute to the sustainability of food systems globally.

Keywords: dietary changes, displaced impacts, food consumption, international trade, local production, virtual water, water footprints

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INTRODUCTION

Globalization and the intensification of the international trade in food has increased the spatial separation of consumption from production (Porkka et al., 2013; Kastner et al., 2014). Calories traded in international food markets have more than doubled in the past 20 years. Currently, around a quarter of food produced for human consumption is traded internationally (D'Odorico et al., 2014), approximately one-fifth of the global virtual water relates to production for exports (Hoekstra and Mekonnen, 2012) and around 80% of the global population live in net-importing countries (Porkka et al., 2013). As the food systems between countries become more interconnected, the consumption in one region has consequences in another region. The socio-economic implications can be positive when contributing to economic growth and creating employment in the production areas. However, globalization has also led to an increase in the outsourcing of resources such as land or water used in agricultural production as consumers withdraw limited resources from distant locations (Steen-Olsen et al., 2012; Meyfroidt et al., 2013). Therefore, countries, businesses and individuals should be conscious of the potential impacts taking place also in the primary production areas.

Although modern agriculture, especially the Green Revolution, has been a successful solution for increasing food production for a growing population (Conway and Toenniessen, 1999), it has also caused considerable environmental damage, such as biodiversity loss, species extinction, degradation of water quality, salinization of the irrigated lands, excessive use of pesticides and extensive loss of arable land (Pimm and Raven, 2000; Foley et al., 2005). Agriculture is the largest user of the land, occupying altogether about 38% of the Earth's terrestrial surface (Ramankutty et al., 2008). Food imports are globally used to overcome the local limits in countries with high pressures from population growth (Porkka et al., 2017) whereas in those parts of the world with vast resources, such as Finland, the increase of food imports over the past decades (Sandström et al., 2017), is mainly driven by globalization and economic interest (see e.g., Anderson, 2010).

Along with the globalization of food production systems, cultivation of many primary crops has become concentrated into a few specific geographical regions. Soybeans are among the most striking examples of this kind of concentrated production. This tends to reduce the diversity of crop rotations and landscapes in those regions but also elsewhere due to low competitiveness if the production is fragmented and less industrial.

To reduce the displaced environmental pressures, an opposite consumption trend to globalization has emerged, especially in northern Europe. It emphasizes each country's own production portfolio (see e.g., Cowell and Parkinson, 2003; Granvik, 2012) and consumer preferences for locally produced food (Nygård and Storstad, 1998; Norberg-Hodge et al., 2002). When the consumer is closer to primary production, some environmental impacts of agriculture (e.g., on freshwater quality and biodiversity) are more concrete, which might increase awareness and even influence consumer preferences and habits (Reisch et al., 2013).

In this, paper we focus on water use embedded in the crop trade as an example of a displaced environmental pressure. The water footprint can be used as an indicator of freshwater quantities used for certain products or services directly or indirectly (Hoekstra, 2003). Virtual water is another approach to analysing the embedded water use in trade. These concepts can be defined as the sum of the quantities of water used in all the production processes for a certain good. For analytical clarity water footprints can be divided into three colors—blue, green and gray—depending on the water origin (Hoekstra, 2003). Blue water refers to the amount of surface and groundwater used in the production, whereas green water refers to the amount of rainwater consumed (Mekonnen and Hoekstra, 2011). The amount of green water consumed is, therefore, more related to the land use impacts of crop production. Gray water refers to the amount of fresh water needed to assimilate the pollutants to meet specific water quality standards (Mekonnen and Hoekstra, 2011). Although water availability is also closely related to water pollution, gray water is not analyzed in this study, and the focus is only on blue and green water.

The global virtual water trade (e.g., Hoekstra and Hung, 2002; Oki and Kanae, 2004; Yang et al., 2006; Dalin et al., 2012) as well as studies on the regional or country-level on virtual water trade and water footprints have been studied extensively (see e.g., for the EU: Antonelli et al., 2017; China: Zhang et al., 2011; Zhang and Anadon, 2014; UK: Yu et al., 2010; Israel: Shtull-Trauring and Bernstein, 2018; and Finland: Nikula, 2012; Sandström et al., 2017). In addition, there are studies for certain countries and regions that have analyzed the potential of the reallocation of food production mainly from cropland efficiency perspective to meet the consumption demands with local production (see e.g., for the UK: Cowell and Parkinson, 2003; Sweden: Röös et al., 2016; Portugal: Cardoso et al., 2017; USA: Zumkehr and Campbell, 2015). However, to our best knowledge, the country-level potential for reallocation of food production from the water use efficiency point of view has not been studied previously. In global scale, international trade has lowered the freshwater use (Fader et al., 2011; Dalin et al., 2012; Liu et al., 2018) when, on average, traded products are transported from more resource-efficient production areas to less resource-efficient consumption areas. Yet, on regional and country-level scale, not all of the virtual water flows are based on resource efficiency, but instead trade flows are often determined by non-water related economic, political and cultural factors, such as prices, trade barriers and consumption preferences (Yang et al., 2006; Fader et al., 2011). This is clear, when countries such as water abundant Finland import water intensive products also from areas suffering from droughts. Therefore, regional and country level studies focusing on the potential solutions for the sustainability problems, such as examining the reallocation of production from the land and water use efficiency perspective are increasingly called for (Fader et al., 2011).

We chose Finland as our case study, because it creates an interesting test-bed to assess the capacity for replacing some water-intensive imported products with local alternatives. The freshwater resources available for agricultural production are vast in Finland, especially in relation to the proportion of the total population and agricultural land area and are therefore currently underused (Peltonen-Sainio et al., 2015a). Also, cereal monocultures are typical to the primary crop production region of Finland: in the utmost case they only include either barley or oats year after year (Peltonen-Sainio et al., 2017, 2018). Such monotonous crop sequencing has many negative impacts on the sustainability and productivity of agricultural systems (Peltonen-Sainio et al., 2015b, 2017). Despite the potential to diversify its domestic agriculture, Finland increasingly imports many products with high water footprints (Sandström et al., 2017). Finnish crop commodity imports have increased from approximately 1 million tons in the late 1980s to more than 2, 4 million tons in 2010 (Sandström et al., 2014, 2017; FAO United Nations Food Agriculture Organization Statistics Division, 2017).

Agriculture is responsible for about 85% of Finland's total water footprint, while around 43% of the Finnish agricultural water footprint is outsourced abroad (Nikula, 2012).

Reasons behind the current high dependency on e.g., imported soybeans and the monotonous crop choices in Finland are the same as elsewhere in the EU: the dominance of economic forces that favor specialization of production systems over diversification, inefficiency of policy instruments to support diversification of agricultural systems, and the nonexistence of sufficient methods to value the benefits of more diverse cropping systems for the farm economy and environment (Zander et al., 2016; Lötjönen and Ollikainen, 2017; Peltonen-Sainio et al., 2018). However, there are ambitions on national level to make the Finnish crop production systems more sustainable. For example, the Finnish Cereal Strategy (MMM, Ministry of Agriculture, and Forestry of Finland, 2016) concluded that the overproduction of often low-quality bulk cereals and exporting oats and barley as native, non-processed grains should be strategically reduced and replaced by alternative, domestic choices and processed commodities because bulk-production is more vulnerable to disturbances in domestic markets (Peltonen-Sainio et al., 2018). Therefore, the strategy supports the sustainable intensification of high-latitude agricultural systems through the use of more diverse crop choices (especially rapeseed and grain legumes) (Peltonen-Sainio et al., 2018).

Our article aims to address the above identified research gap on lack of assessments of the potential to reduce the outsourced water use, by replacing the imported crops with local crop production. We focus on Finland's displaced water use and the maximal potential to reduce the negative impacts of selected imported crops through local solutions, from the land and water use efficiency perspective. With the analysis, we aim to provide one part of the larger portfolio of solutions, on how to increase the sustainability of the food systems (see e.g., Kummu et al., 2017). With our findings, we highlight the current, hidden opportunities from the natural resources point of view that can later serve as a basis for future expansion of the focus to e.g., consumer preferences or economic feasibility. Nevertheless, our suggested approach is in line with the current strategy of cereal production, as presented above, and thus feasible from that point of view.

To achieve our aims, we use a novel approach by combining national level statistics of the potential to increase the production of certain crops, water scarcity calculations to identify the most impacted regions of Finnish imports as well as water footprint calculations to assess the impacts of the replaced production on water use. Based on the impact assessment, we ended up analyzing the consequences of replacing the imports of three products with national substitutes, being: rice (*Oryza sativa L.),* soybeans (*Glycine max L.)* and rapeseed (*Brassica napus L.).* Together they accounted for 16% of all the blue water imports and 30% of all the green water imports to Finland in 2011.

MATERIALS AND METHODS

The research was designed and conducted as follows: First, we analyzed the crop imports into Finland from 1986 to 2011, and second, we calculated the related virtual water embedded in the imported crop-based commodities. Third, we analyzed the water scarcity in the production regions, and fourth, we identified the most important products imported to Finland from the regions suffering from water scarcity. Three primary crops—rice, soybeans and rapeseed—were selected for closer analysis. Finally, we analyzed how much the domestic production could replace the imports of the selected commodities and from where the virtual water imports would be reduced (**Figure 1**).

Virtual Water Imports

We calculated the amount of virtual water embedded in the crop imports into Finland using data on the crop imports from 1986 to 2011. This time period was chosen because of the availability of the trade analysis data. We analyzed both blue and green water. In this study, we accounted only for the water use in primary production (i.e., cultivation of the crop), and thus we did not take into account the amount of water used in the processing, packaging or transportation of crop-based commodities.

We used agricultural trade data from Kastner et al. (2011) and Kastner et al. (2014). They presented an approach applying bilateral trade data from FAOSTAT (FAO United Nations Food Agriculture Organization Statistics Division, 2017) and linking material flows for almost 450 crop and livestock products from production through intermediate transporting or processing countries to the final consumption location in over 200 nations. This was done by assuming that imports and domestic production contribute to the domestic consumption in proportional shares. This enabled the identification of the original production country of the consumed commodities, which was essential in analyzing the water used in primary production. A complete description of the approach and results of the global analysis of the international food trade was published in Kastner et al. (2014). We used the data for Finland available until 2011. Country-specific crop yield data (FAO United Nations Food Agriculture Organization Statistics Division, 2017) was used to convert imported quantities into estimates of cropland areas.

Water use was calculated by multiplying the amount of crop commodities imported from a country with crop and country-specific blue and green water coefficients from Mekonnen and Hoekstra (2011). These water use coefficients were calculated as the average for the period of 1996–2005. However, crop water requirements may change over time as crop yields increase through agricultural development. Due to the fixed water use efficiency, it was not possible to take into account the possible changes over time. The use of time-specific data on the water use would improve the accuracy of the estimates and this remains an important task for future research.

Water Scarcity in the Production Regions

Water scarcity in the production countries was used as one factor for choosing the case crops (see more on section Identification of the Case Crops). Water scarcity generally refers to the condition where the demand for water by all sectors, including the environment, cannot be completely satisfied because of the impact of water use on the supply or quality of water (Falkenmark

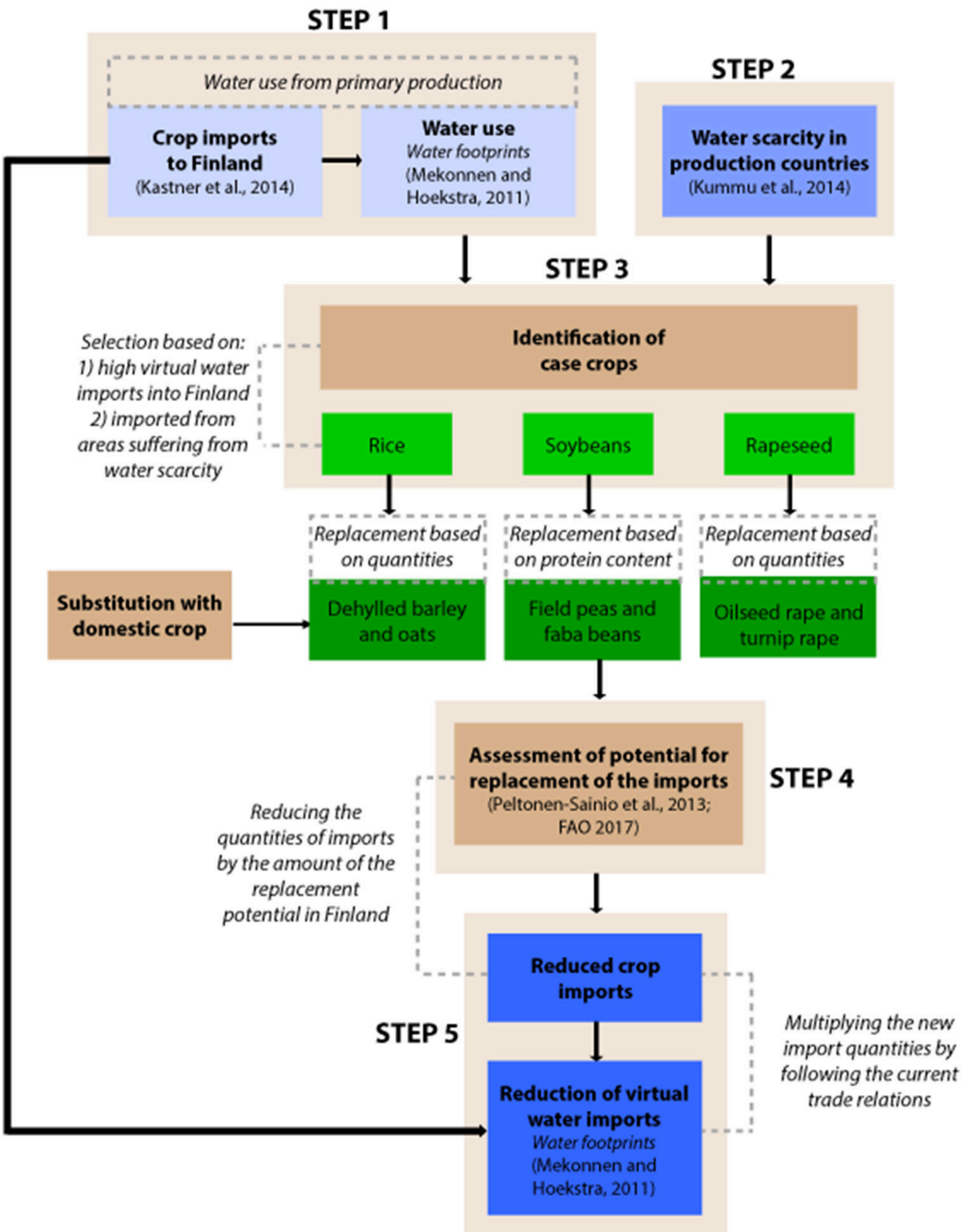

FIGURE 1 | Framework for the accounting used in this study. Principal data sources are presented in parenthesis.

et al., 1989; Rockström et al., 2009; Liu et al., 2017). There are many different ways to define water scarcity–whether the focus is on the water stress index (Falkenmark et al., 1989) or on basic human water requirements (Gleick, 1996). Recently, indicators have been developed where the assessment of water scarcity includes green water in addition to blue water (Falkenmark and Rockström, 2004; Rockström et al., 2009; Gerten et al., 2011; Kummu et al., 2014).

The green-blue water scarcity indicator used in this study was originally developed by Gerten et al. (2011) and later developed by Kummu et al. (2014). The availability of green-blue water was taken into account and aggregated in the 309 global food production units (the current agricultural areas, agronomic practices and population levels) that included an average size of 467 * 10^3 km^2 and an average population of 19.6 million people (Kummu et al., 2014; Porkka et al., 2016). The food production units were compared to the amounts of water needed to produce a reference diet of 3,000 kcal cap^{-1} day^{-1} (Gerten et al., 2011). A region is considered to be green-blue water scarce if its domestic availability of green and blue water falls below the green and blue water demand. Water scarcity is categorized into the following groups: "critical scarcity" (<0.5), "high scarcity" (0.5–1), "moderate scarcity" (1–1.5), "approaching scarcity" (1.5–2), and "no scarcity" (>2). A complete description of the method and its limitations can be found in Kummu et al. (2014).

We applied the green-blue water scarcity data aggregated from food production units on a country level using weighted averages for food production (EarthStat, 2017). When averaging the water scarcity data from a more detailed level to a more aggregated level, large countries containing both water-sufficient and water-scarce areas can appear as countries with sufficient water availability. Therefore, studies tracking supply chains in more detail are needed to achieve more specific results of the production impacts.

Identification of the Case Crops

In the next step, we identified the most important products imported into Finland from the regions suffering from water scarcity. We did not look at the products imported on a small-scale—even from the most severe water scarcity regions—but instead concentrated on the products that: (1) contributed by, on average, more than 5% to the Finnish virtual water imports embedded in crop products, and/or (2) are imported to Finland from production areas suffering from water scarcity. Based on these criteria we selected three products, rice, soybeans and rapeseed and analyzed the potential in Finland to replace their imports with local production of the same or alternative products. Although rice contributes only very little (approximately 1% in 2011; FAO United Nations Food Agriculture Organization Statistics Division, 2017) to the calorie and protein supply of the overall average Finnish food consumption, it is an important contributor to the blue water imports into Finland. Soybeans are mainly used as animal feed and consumed indirectly, and they are also important contributors to both blue and green water imports to Finland. Rapeseed is consumed indirectly as animal feed but also directly as vegetable oil, and it was selected because of its large share in green water imports.

Coffee (*Coffea arabica L.),* (blue and green water) and tropical fruits (blue water) were also important products and accounted for high virtual water imports into Finland. However, it is not plausible to cultivate these or any comparable products in Finland and, therefore, replacing their consumption with domestic production is impossible without dramatically changing Finnish consumption habits or agricultural practices. Hence, they were excluded from further analysis.

Potential to Replace Imports of the Selected Commodities

Changing trade relations to import crops from countries that do not present national water scarcity issues could contribute to reducing the pressure of displaced water use. However, large-scale importing decisions are more commonly influenced by prices and other factors instead of environmental concerns (Carrigan and Attalla, 2001), and this kind of analysis was not the focus of this study. Instead, we analyzed the potential to use the domestic production of the same or substitute crops to replace the imports.

The cultivation areas of locally grown crops in Finland were retrieved from the Official Statistics of Finland (Official Statistics of Finland, 2018). Rice imports were theoretically considered for replacement by dehulled barley (*Hordeum vulgare L.)* and oats (*Avena sativa L.*), while soybean imports were theoretically considered for replacement by domestic protein crops, faba beans (*Vicia faba L.*) and peas (*Pisum sativum L.)* and rapeseed imports were considered for replacement by domestic oilseed rape and turnip rape (*Brassica rapa L.)*.

The potential for increasing domestic protein crop and rapeseed production was based on Peltonen-Sainio et al. (2013). They estimated the theoretical potential of the expansion of legumes to be 238,000 ha and rapeseed as 173,000 ha in Finland. This was calculated taking into account regional production risks and rotation requirements. Currently, cereals dominate the Finnish agricultural land use (Peltonen-Sainio et al., 2017). The expansion of legumes and rapeseed would take place at the expense of cereal cultivation, reducing the overproduction of low-quality bulk cereals and their exports as non-processed grains, following the conclusions of the Finnish Cereal Strategy (MMM, Ministry of Agriculture, and Forestry of Finland, 2016). Also, the narrowing of the currently high yield gaps in the cereal production would lead to decreasing cropland need for cereal production (Peltonen-Sainio et al., 2015b). Consequently, this would also contribute to the diversification of Finnish agriculture by breaking the monotonous cereal rotations. For this reason, we do not consider that further cropland expansion, e.g., by clearing forests would be needed. Deforestation would also go against all the current land use policies in Finland and for this reason it was ruled out of the equation.

Rice does not adapt to temperate high-latitude conditions (≥60°N), and hence, it cannot be cultivated in Finland. We considered dehulled barley and oat grains to be potential alternative crops for imported rice because of their use in place of rice in Finnish cuisine. However, Finnish crop rotations suffer from barley and oat monocultures (Peltonen-Sainio et al., 2017), and hence, further expansion of their cultivation areas was considered to be unsustainable. Therefore, the capacity to replace rice with barley and oats was solely based on Finland's export volumes, assuming that the quantities of rice imported would be replaced by reduced exports of barley and oats. Naturally, this would imply changes in consumption habits. The nutritional contents of oats and barley, in terms of their calories, protein and fat, are higher in comparison to paddy rice (FAO United Nations Food Agriculture Organization, 2001), and therefore the replacement would improve the nutrient content of Finnish food consumption. However, as overconsumption of food is an increasing health problem in highly developed countries such as Finland, the health aspects of increased cereal consumption would need to be carefully assessed.

Soybeans are another important contributor to both blue and green water imports. Under the climatic constraints of Finland, including long days in the summer months, it is not reasonable to cultivate soybeans as it is a short-day plant. Therefore, similarly to rice, we analyzed the potential to replace soybeans imports with substitute crops–in this case faba beans and field peas, because of their high protein content and therefore their potential to replace soybeans in animal feed (Peltonen-Sainio et al., 2013). When analyzing the replacement of soybeans with grain legumes, we converted the quantity of soybean imports into protein quantities (FAO United Nations Food Agriculture Organization, 2001) and analyzed how many tons of faba beans and field peas this would imply.

The potential to replace rapeseed imports was compared to the potential to increase domestic rapeseed production in Finland. Since it is a question of the same product, the replacement would be simpler and no consumption changes would be necessary.

Reduction of Virtual Water Imports

Finally, we analyzed the maximum theoretical potential of how much and from where the virtual water imports would be reduced if all the potential for substituting rice, soybeans and rapeseed imports could be harnessed in Finland. This was done by reducing the quantities of imports by the amount of the replacement potential in Finland and multiplying the new import quantities with the shares of crops imported from different countries. This method assumed that no changes in trade relations would take place. In practice, changes in trade quantities could also result in changes in trade relations and vice versa. To include this aspect was, however, was beyond the scope of this paper. The potential for substitution is analyzed only on a theoretical level. Therefore, although the water use pressure caused by Finnish consumers would be reduced, it would not necessarily mean reduction in the water use in the current production countries. The water savings from Finland's trade could result in exports merely being aligned to another country.

RESULTS

Virtual Water Imports

Finland annually imports approximately 100 million m^3 of blue water through the trade of crop-based commodities (**Figure 2A**) (See also **Data Sheet 1** in the Supplementary Materials). Rice is the largest contributor to the blue water imports because of high water consumption in the primary production phase (**Figure 2A**), although the per capita rice consumption in Finland is relatively low–only 4 kg^{-1} cap^{-1} year^{-1} compared to the world average of 54 kg^{-1} cap^{-1} year^{-1} (FAO United Nations Food Agriculture Organization Statistics Division, 2017). Blue water imports of rice remained relatively stable during the study period (**Figure 2A**). The amounts of rice imports increased from approximately 20,000 tons in the late 1980s to more than 25,000 tons in the 2010s. This can be partly explained by changes in trade relations, since the overall amount of international trade expanded after Finland joined to the European Union in 1995 (see also **Figure S1**). A drop in the water imports at the beginning of the 1990s' can be linked to the economic depression, and it is also visible in the overall food imports to Finland in that time (FAO United Nations Food Agriculture Organization Statistics Division, 2017).

Additionally, coffee, oranges (*Citrus sinensis L.),* mandarins and clementines (*Citrus reticulata Blanco*), other fresh fruits and soybeans contribute to the blue water imports into Finland, both because of their high water footprints and large import volumes. In 2011, these six products accounted for 45% of all blue water imports to Finland. The blue water imports from other European countries increased from 16% in 1986 to more than 40% in 2011, when most blue water was imported from Spain and Italy (see also **Figure S2**).

The green water imports have more than doubled between 1986 and 2011, from approximately 1200 million m^3 to more than 2,600 million m^3 (**Figure 2B**). In the same period, the population in Finland increased from 4.9 to 5.4 million (FAO United Nations Food Agriculture Organization Statistics Division, 2017). The increase has been therefore driven by both the population growth and the general trend in increasing agricultural trade in Finland (Sandström et al., 2017) (see also **Figure S1**). In 2010, coffee, soybeans, rapeseed, wheat (*Triticum aestivum L.),* palm oil (*Elaeis guineenses Jacq*.) and cocoa beans (*Theobroma cacao L.)* were the major contributors to green water imports (**Figure 2B**). In 2011, these six species accounted for 77% of total assessed green water imports into Finland. Rapeseed imports into Finland increased significantly from 1986 to 2011, and this can also be seen in the green water increases embedded in the rapeseed imports (**Figure 2B**). The green water imports from other European countries increased from 6% to almost 30% from 1986 to 2011 (see also **Figure S3**). Latin America has, however, remained the most important green water import region to Finland, contributing 30–50% of the green water imports during the past 30 years.

Crop Imports and Water Scarcity in the Production Regions

Figure 3 displays the combined blue and green water imports into Finland together with the green-blue water scarcity in the production countries. Imports of green virtual water are much higher than the blue water imports. In 2007–2011, almost 96% of the water used to produce the imported crops was green water and only 4% was blue water.

When examining water scarcity, it is important to differentiate between blue and green water since the water resources are different and their environmental implications might be challenging to define (Fader et al., 2011). Also, the purpose of use for blue and green water are different—blue water use is often more critical because multiple acto.rs compete for the same surface—and groundwater resources, and therefore, it has a higher opportunity cost (Hoekstra, 2010). Finland imports large quantities of blue water from southern Europe, northern Africa, southern Asia and the Middle East. Some of these areas suffer from water scarcity seasonally (Mekonnen and Hoekstra, 2016) or throughout the year (Kummu et al., 2010; **Figure 3**). The products related to the highest virtual water imports from these water-scarce areas are rice, citrus fruits, soybeans, coffee, castor oil seeds (*Ricinus communis L.*), fresh vegetables and other fresh fruits. Products imported in smaller quantities from severely water-scarce regions include dates (*Phoenix sp.),* grapefruit [*Citrus × paradisi Magfad*, including pomelos (*Citrus maxima Merr.*)], sesame seeds (*Sesamum indicum L.),* safflower seeds

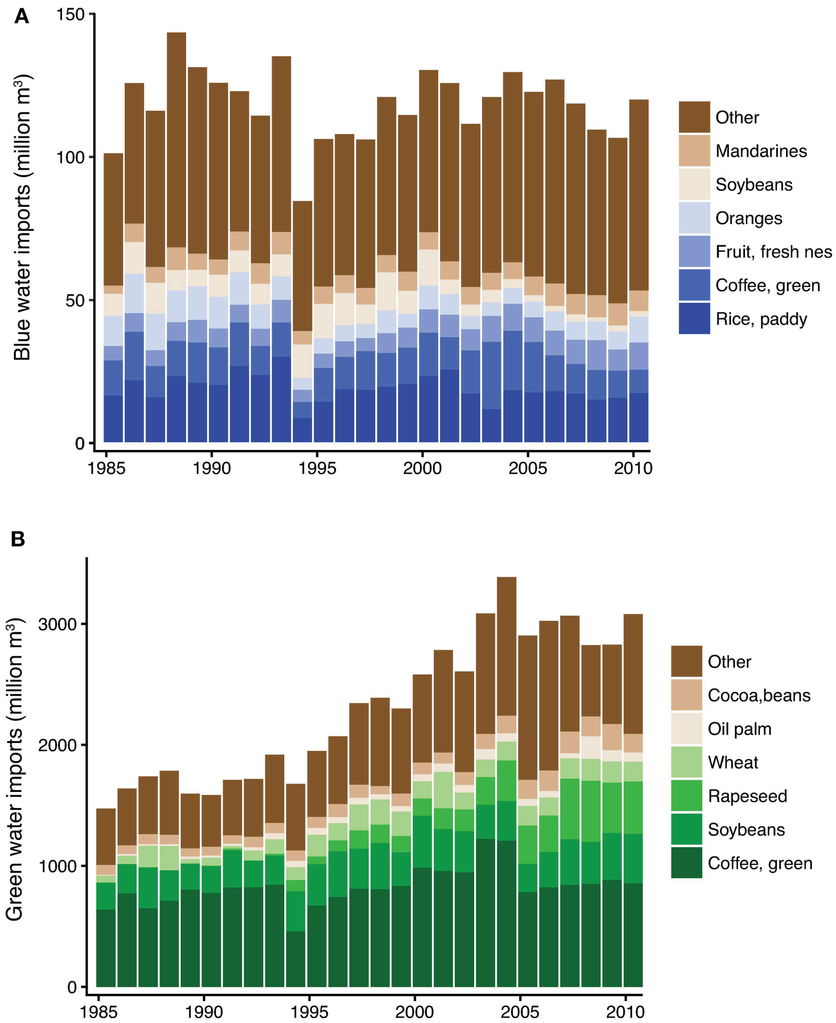

FIGURE 2 | Blue water **(A)** and green water **(B)** imports of the main crops imported to Finland during 1986–2011.

(*Carthamus tinctorius L.),* avocados (*Persea americana P. Mill.)* and sweet potatoes (*Ipomoea batatas Lam.).*

Potential to Replace the Imports in Finland

In 2010, the cultivated barley area in Finland was 420,000 ha and the cultivated oat area 280,000 ha. In 2010, more than 372,000 tons of barley and 336,000 tons of oats were exported, while 2,000 tons of rice were imported. Hence, theoretically all the imported rice could be replaced by the domestic production of barley and oats in Finland without expanding their cultivation areas (**Table 1**).

In 2009–2011, approximately 188,000 tons of soybeans were imported annually into Finland. This corresponds to 305,000 tons of faba beans (120,000 ha) or 318,000 tons of field peas (150,000 ha) that would be needed to fully replace the soybean imports. Currently, faba beans and peas are minor crops cultivated only in marginal land areas in Finland, but faba bean areas, in particular, have steadily increased (Peltonen-Sainio et al., 2016, 2017). In 2010, only 7,000 ha of faba beans and 4,000 ha of peas were cultivated domestically (Official Statistics of Finland, 2018). However, there is large potential to increase their production. The diversification of agricultural systems with leguminous crops would provide many ecosystem services because of their high value as previous crops in rotations (Angus et al., 2015). Peltonen-Sainio et al. (2013) estimated that there are 238,000 potential hectares of land which could be used to increase the cultivation of legumes in Finland. Thereby, virtually all the soybean imports could be replaced by cultivating faba beans and field peas in Finland.

The total cultivation area of rapeseed in Finland in 2010 was 110,000 ha. Peltonen-Sainio et al. (2013) estimated that there is 173,000 ha of potential land which could be used to increase rapeseed production in existing fields. At the same time, 245,000 tons of rapeseed were annually imported to Finland in 2009–2011, which corresponds to around 123,000 ha of cropland abroad. Producing the quantities of imported rapeseed

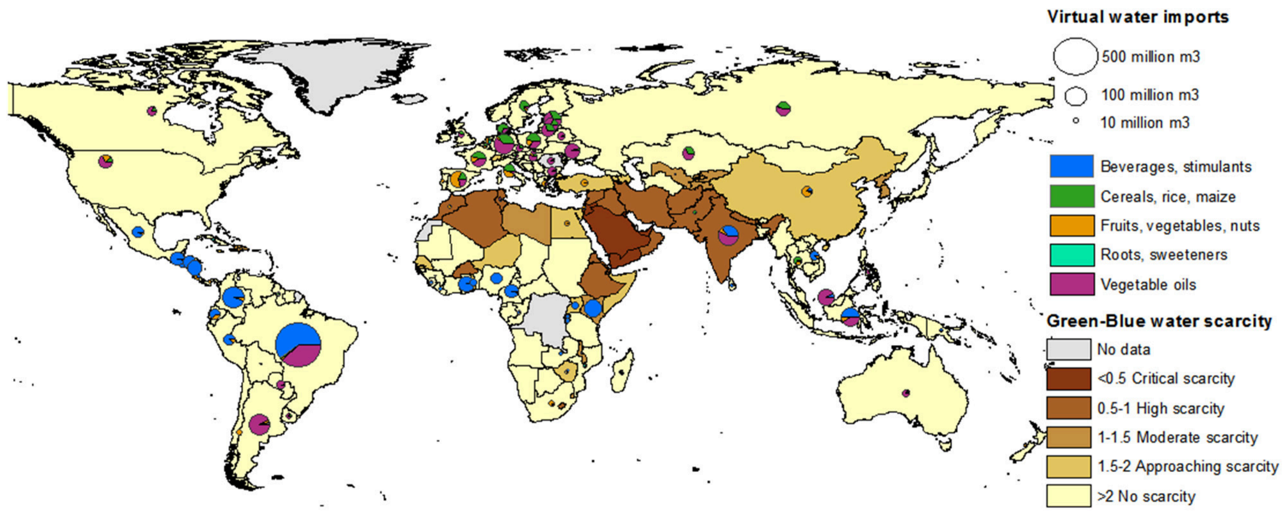

FIGURE 3 | Map of combined green and blue water scarcity (=the availability of green and blue water/requirements in a region, Kummu et al., 2014) and green and blue water embedded in crop imports to Finland (mean of 2007–2011). The size of the pie charts represents the volume of green and blue water imported into Finland and they are sized proportionally by area.

TABLE 1 | The potential reduction of annual virtual water imports (BW, blue water; GW, green water) in the case of replacing rice, rapeseed and soybeans with local production.

Imported product	Imports (mean 2009–2011) [t year^{-1}]	Substitutive domestic product	Potential for substitution [%]*	Reduction of BW imports		Reduction of GW imports	
				[1,000 m^3 year^{-1}]	% of total[a]	[1,000 m^3 year^{-1}]	% of total[a]
Rice	25,000	Barley/Oats	100	16,000	14	22,000	0.7
Soybeans	188,000	Field peas/Faba beans	100	1,800	1.6	380,000	13
Rapeseed	245,000	Rapeseed	98	460	0.4	450,000	16

[a] *By total, we refer to the virtual water imported though total crop imports to Finland in the years 2009–2011.*
**Theoretical potential.*

in Finland, with an average yield of 1.38 tons ha^{-1}, would require 178,000 ha of domestic cropland. There are, however, limitations for the expansion of rapeseed cultivation: increasing risk of disease outbreaks and pest invasion, lack of suitable field parcels and requirement for four gap years in rotation between rapeseed cultivations (Peltonen-Sainio et al., 2013). Even when acknowledging these constraints, a substantial share of 98% of all the imports in 2010 could be replaced by domestic production.

Reduction of Virtual Water Imports

If all the cultivation potential in Finland were to be fully harnessed to replace the imports of rice, soybeans and rapeseed with domestic products, the virtual blue water imports to Finland would be reduced by 16% and the virtual green water by almost 30% (**Table 1**). Reducing the consumption of rice would make the greatest contribution to reductions in virtual blue water, while reducing rapeseed and soybean imports would considerably reduce virtual green water imports.

When analyzing the sustainability of the food system, the question of how much water is used is not as important as the question of where the water is used. If trade relations would remain unchanged in our scenario, replacing the imports of the three analyzed crop products would potentially reduce the blue water use mostly in countries that suffer from water scarcity. The most significant blue water savings would take place in Spain (5,000,000 m^3 year^{-1}), Thailand (2,000,000 m^3 year^{-1}), Pakistan (1,400,000 m^3 year^{-1}) and India (500,000 m^3 year^{-1}; **Figure 4A**). Although the calculated blue water saving quantities are quite small compared to the total amount of water used in the agricultural production in these countries, they are not insignificant. The total reduction of blue water imports is equal to the annual blue water use of more than 18,000 people when using the water requirement for meeting basic human needs of 1,000 m^3 cap^{-1} year^{-1} from the Falkenmark indicator (Falkenmark et al., 1989). However, if overall demand of these crops is elastic and would increase, the reductions of the Finnish imports might be overruled by increased exports to other countries. Yet, we believe, that this kind of analyses are useful in guiding policy-makers and consumers to consider the impacts of their actions with a broader perspective.

Green water use is closely related to land use and also serves as an indicator of land use pressure displaced through trade. Finland imports large quantities of soybeans from North and South America and rapeseed mainly from other European countries.

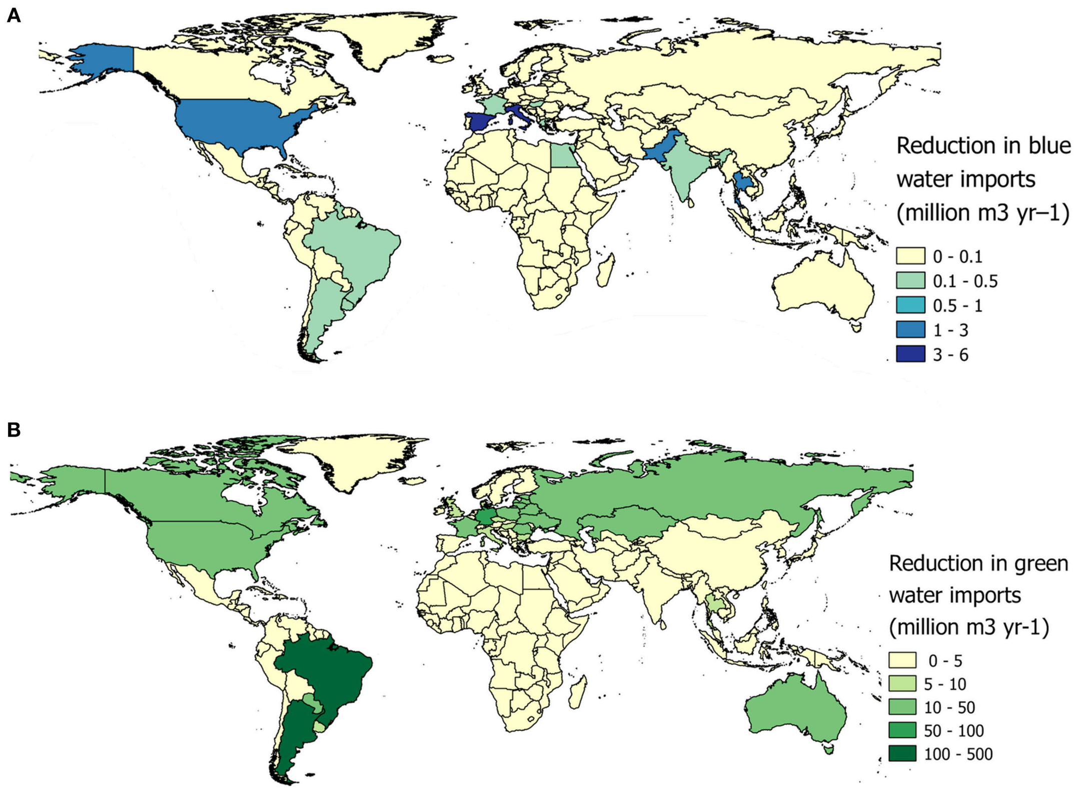

FIGURE 4 | (A) Reduction in blue water imports and **(B)** green water imports (million m^3 $year^{-1}$) if the imports of rice, soybeans and rapeseed would be replaced by the domestic cultivation in Finland.

Reducing the import volumes of the three selected crops would reduce the green water imports by more than 850 million m^3 $year^{-1}$(**Figure 4B**).

DISCUSSION

In this study, we assessed for the first time the virtual water imports of three major import crops (rice, soybeans and rapeseed) together with the potential in Finland to replace them domestically (with barley and oats, field peas and faba beans, and rapeseed respectively). Previously (e.g., Nikula, 2012) has studied Finland's external water footprint, Sandström et al. (2017) have examined Finland's outsourced land and water use and Peltonen-Sainio et al. (2013) have calculated the potential to increase the legume and rapeseed production in Finland. Our combined analysis of the replacement potential and its connection to global water scarcity, produces valuable insights on the impacts that one individual country can have. At the same time, the analysis also offers practical information for consumers and policy-makers about the displaced impacts of consumption. Although certain simplified assumptions have been made, the results of this analysis can be interpreted as the maximum replacement potential for Finland for these three crops. At the same time they can form part of more comprehensive analyses looking for potential solutions to increase the sustainability of food systems.

Potential to Contribute to Global Water Scarcity Alleviation

Finland imports water-intensive products also from areas that are currently suffering from water scarcity. For example, citrus fruits are imported in large quantities from Egypt, Israel and Spain and coffee from Kenya, Uganda and India that are affected by water scarcity. These products cannot be grown in Finland due to climatic constraints and therefore their replacement by domestic production is not possible. Altogether, Finland imports around 30% of its consumed food (Knuuttila and Vatanen, 2015). Food imports have contributed to the diversification of Finnish diets and have enabled the local limits posed by the northern climate for the domestic agriculture to be overcome. This has also led to the sparing of land in Finland for other uses. However, importing food from abroad has also led to the displacement of environmental impacts related to primary production. There are several ways to reduce the negative impact of food trade. Our research is focused on the replacement of virtual water embedded in the imports of soybeans, rice and rapeseed with domestic production.

Soybeans are a major import crop into Finland with large quantities of embedded virtual water. They are mainly imported into Finland for animal feed because of the high protein content and favorable amino acid composition (Peltonen-Sainio and Niemi, 2012; Peltonen-Sainio et al., 2013). Soybeans present an extreme example of globally strongly polarized agricultural production, where the soybean production is mainly concentrated in a few countries (FAO United Nations Food Agriculture Organization Statistics Division, 2017), and this potentially exposes international trade to possible distortions, sustainability problems and price volatility. Even at the European level, the self-sufficiency of soybean meal is only about 3%, while it supplies 64% of the protein-rich raw material for feeds (de Visser et al., 2014). South and North Americas are key players in the soybean market, and they also provide most of the soybeans to Finland. This polarized market has reduced the competitiveness of local protein sources such as peas and faba beans in many countries, including Finland (Peltonen-Sainio and Niemi, 2012; Peltonen-Sainio et al., 2013). The diversification of crop rotations and agricultural landscapes is highlighted as an important means to improve the overall sustainability of agricultural production. Hence, it is a core measure when sustainably intensifying agricultural systems, and when improving resilience to climate change and variability as a part of climate-smart agriculture (Stoate et al., 2001; Soussana et al., 2012). Therefore, replacing soybean imports with domestic protein sources would both alleviate the land and water use pressures especially in South America and contribute to the diversification of Finnish crop rotations.

Rice imports into Finland have increased from approximately 15,000 tons in 1986 to 25,000 tons in 2011 (FAO United Nations Food Agriculture Organization Statistics Division, 2017) and rice is mainly imported for direct food consumption. The majority of the rice is imported from Spain and Italy or from countries such as Pakistan and Thailand where water scarcity can be a severe threat. Rice production causes the overuse and depletion of groundwater in many parts of the world due to large production areas and high groundwater use. Rice exports are responsible for almost one-third of all the groundwater depletion transferred globally (Dalin et al., 2017). This is a growing problem especially in countries such as India and Pakistan that together account for over 40% of global groundwater depletion (Dalin et al., 2017). These countries are also important rice exporters to Finland. In many of these regions, especially in the Middle East and South Asia, the existing water scarcity combined with the climate and demographic change, is expected to become even more severe in the future (Rockström et al., 2009).

The majority of the rapeseed imports into Finland come from other European countries and Russia, where water scarcity is not a major issue. Most of the rapeseed imported into Finland is rainfed i.e., mainly green water is used in the production. Currently, Finland is the northernmost, large-scale oil crop production country with rapeseed as the principal production choice. However, rapeseed imports have been increasing considerably during the past decades (FAO United Nations Food Agriculture Organization Statistics Division, 2017) because of declined national yield trends and increased production uncertainties that were both recently further challenged when the usage of neonicotinoids (pesticide) were banned in the EU (Peltonen-Sainio et al., 2016). Therefore, addressing the drivers of the declining national yield trends should be a priority to ensure profitable domestic production. In comparison with the many water-scarce countries, Finland is rich in water and land resources (Peltonen-Sainio et al., 2015a), and is not expected to suffer from water scarcity even with a changing climate (Ruosteenoja et al., 2017). Hence, the role of high-latitude countries, such as Finland, as a food production country could become more significant with the changing climate (Peltonen-Sainio et al., 2009).

Implications on Individual and National Scales

Finland is a welfare country where public expenditure plays a significant role. This analysis can be viewed as an awakening for the first steps toward change for the public and for policymakers showing the impacts of large-scale changes in consumption habits. One potential way to achieve an influence on a national scale is to direct the public expenditures on meals in nurseries, schools and work cafeterias toward domestic choices. Also, consumers on the individual level have the power to change their food consumption habits in a more sustainable direction, especially in the rich, developed countries. Food consumption patterns are not only based on the nutritional needs but also on personal preferences, such as taste, odor and texture alongside culture and ethics, which all play a significant role when choosing a personal diet (Carlsson-Kanyama, 1998).

We acknowledge that the 100% substitution presented in the **Table 1** is not realistic from the consumers' point of view. Especially challenging would be the large-scale changes in the consumption of rice and its replacement with oats and barley. However, both oats and barley have been traditionally used in Finnish cuisine before imported rice and their use as food has increased again due to novel products available for consumers. Regarding soybeans, their replacement is easier because they are mainly used as animal feed in Finland (Peltonen-Sainio and Niemi, 2012; Peltonen-Sainio et al., 2013) and the industry already has fixed processes for faba beans. Therefore, replacing their use with faba beans or field peas would not lead to direct major changes in consumption habits. The differences in protein content and amino acid composition, as well as digestibility compared to soybeans, should, however be taken into account in animal feeding (Partanen et al., 2001, 2006; Jezierny et al., 2010). A smaller share of imported soybeans is consumed directly as food, mainly replacing meat in the diet.

Due to Finland's northern location and limitations caused by short growing season, we acknowledge that importing certain commodities will also be necessary in the foreseeable future. The dependency of a northern country, such as Finland, on the global food markets is significant (Knuuttila and Vatanen, 2015). Currently, Finnish agriculture is able to meet the needs of the consumers quite well in normal conditions based on the relation between domestic production and consumption (Niemi et al., 2013). The import content of the entire food market was 28% in 2012 (Knuuttila and Vatanen, 2015). However, looking only at the self-sufficiency rates of agricultural production neglects the fact that Finnish agriculture itself is dependent on many imported resources such as fertilizers and chemicals, fuel, protein feed and work machines (Niemi et al., 2013; Knuuttila and Vatanen, 2015).

Even though Finland will most likely remain dependent on the imported foodstuff also in the future, replacing part of the consumption of the studied crops with domestic choices would increase direct self-sufficiency. In the case of disturbances in global markets, domestic production and exports can serve as a buffer against shocks in the global trade (Fader et al., 2016). This also works the other way round: food imports may help to buffer local climate and economic shocks (see e.g., Liu et al., 2014). Overall, the future of the global food system might be challenging to predict due to its complexity and interconnections between different drivers (Godfray et al., 2010). Already now in Finland, and elsewhere in Europe, farm sizes are increasing and the number of farms is decreasing (Niemi et al., 2014; Niemi and Väre, 2017). Therefore, keeping primary production in Finland would help to maintain the crucial agricultural know-how in the country.

Limitations of the Study and the Way Forward

The aim of this study was to examine the potential to reduce Finland's outsourced environmental pressure in water-scarce countries and provide practical information about the impact that one country can have on another. In this study, the water use reductions are considered only in the exporting countries. The water footprint of the Finnish replacement crops has not been calculated because increasing the domestic agricultural production can be done without leading to water scarcity in Finland.

Apart from imported water volumes, additional information is vital to assess the overall impacts of the production for a certain good or service (Hoekstra, 2003; Mekonnen and Hoekstra, 2011). Therefore, the use of multiple indicators should be encouraged (see e.g., MacDonald et al., 2015; Sandström et al., 2017). When comprehensively analyzing the sustainability of a food system, both natural and human systems, such as consumer preferences, diet changes over time and demographic changes should be considered.

It is also important to remember that the production of exported goods can be, and often is, an important source of income for the production countries that could be affected by reduced exports. Because the quantities of rice, soybeans and rapeseed imported into Finland are relatively marginal compared to the total production in the exporting countries, the economic losses to the production countries would also remain marginal. Future research should be focused also on the socio-economic implications of changes in trade relations.

A single country can make only a minor contribution to global-scale changes. However, concrete solutions must be established on a local scale, since the regulations related to food trade and adaptation to the climate are often made on the national scale.

CONCLUSION

Water scarcity is an increasing problem in many parts of the world and without appropriate action, water scarcity is predicted to become a key geopolitical issue that will affect the entire globe through the shared economic system. Countries with a strong economy can afford to import commodities in order to assure the national food security, despite possibly scarce resources.

In Finland, water resources are not scarce, but Finland still imports large amounts of water-intensive agricultural products. The quantities of virtual water imported are not as important as the question of where the water use occurs. Our analysis showed that Finland imports crop products also from areas suffering from water scarcity. We analyzed the theoretical potential to replace the imports of rice, soybeans and rapeseed with local production. The replacement would reduce the outsourced blue and green water use of the crop imports by 16% and 30% respectively, and at the same time it would increase the diversity in Finnish agricultural production.

Even though in our case study, the reduction of the blue and green water imports was relatively small on the global scale, this opens up a much-needed dialogue on the potential to reduce virtual water consumption through local production. It represents a real-life sustainability problem with a reproducible solution of how increases in local production can reduce the international virtual resources trade flows and displaced environmental impacts while contributing positively to the sustainability of local production.

AUTHOR CONTRIBUTIONS

The study was designed by all three authors. VS conducted the data analysis. VS and EL visualized the data. All three authors contributed to the interpretation of the results and the writing of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2018.00067/full#supplementary-material

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